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Abstract
Laser isotope purification of lead for use in semiconductor chip interconnects

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Lead is a key material used in the Controlled Collapsed Chip Connection (C^4) technique that is used to form connections between the IC chip and the package. One isotope of lead, ^{210}Pb, is radioactive with a half-life of 22.3Y, formed as a byproduct of uranium decay, and is found at low concentrations in lead ore. The alpha emissions that come from the ^{210}Po daughter of ^{210}Pb decay can cause soft errors in the memory or logic circuitry of the integrated chip. This may place limitations on C^4 usefulness or impose design constraints in future generations of ICs, particularly as reductions in feature size and operating voltage increase sensitivity to alpha emissions.

Over the past 20 years the Lawrence Livermore National Laboratory has developed a laser-based method for separating isotopes. An element is heated within a vacuum vessel with either an electron beam or, in the case of more volatile materials, a resistance heater. Material vaporizes and streams upward forming a low density atomic vapor. This vapor is illuminated with multiple laser wavelengths and is stepwise resonantly excited until it has enough energy to ionize. The lasers are set at precisely controlled frequencies and have sufficiently narrow frequency bandwidth to ionize a single isotope. The resulting isotopically-enriched plasma, formed between pairs of charged extractors, is electrostatically separated and condensed. This general method is called Atomic Vapor Laser Isotope Separation (AVLIS).

The focus of the AVLIS program has been the enrichment of uranium for use in commercial nuclear reactors. Plant scale component technologies have been demonstrated including: 1) Copper lasers, which convert electrical energy to >10kW of laser light, that have been operated for millions of unit hours; 2) Dye lasers which convert the copper laser light to a precise narrow bandwidth wavelength; and 3) Separator systems which process metric tons of uranium. Integrated demonstrations have produced hundreds of kilograms of reactor grade uranium (enrichments between 2% and 5% ^{235}U). The program has also enriched multi-kilograms of erbium, gadolinium, and others.

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The United States Enrichment Corporation (USEC) has been granted all rights to AVLIS technology previously owned by DOE. USEC has submitted a privitization plan to the President and Congress and expects approval in 1996. The USEC Board of Directors decided in 1994 to take steps toward the deployment of an AVLIS uranium plant. USEC is sponsoring at LLNL the completion of technology development and preliminary uranium plant design in FY96 and FY97.

Under USEC sponsorship, LLNL is also investigating other industrial and medical isotope separations for potential future business. Initial investigation into lead isotope purification indicates application of AVLIS technology developed for the uranium program is technically and commercially feasible. Spectroscopic studies have identified photoionization pathways which will efficiently and selectively ionize ^{210}Pb. During FY96 the specific laser and separator hardware required to process lead will be prototyped. If sufficient commercial interest develops, USEC will consider offering limited quantities of lead depleted in ^{210}Pb in FY97, and ton quantities beginning in FY98.